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ABSTRACT

Telesensory Systems, Inc. (TSI) was awarded a contract to design, develop, and test Optacons (Optical-to-Tactile Converter) and perepheral equipment. Optacons are direct-translation reading aids for the blind. The text summarizes the engineering design, manufacturing activities, field test procedure and results, and it provides recommendations for more effective implementation in the future. Among these conclusions were that although a "mass-production" of Optacons was not achieved, Optacons and related support equipment are amenable to production-line assembly techniques; production efficiencies made as a result of this contract alone reduced the price of Optacons by 30%. (EMH)

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Final Report

Project #101

Contract #OEC-0-71-4415 (607)

MANUFACTURE OF OPTACONS FOR A FIELD TRIAL WITHIN ELEMENTARY AND SECONDARY SCHOOLS

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IR 003 252

U.S. Department of
Health, Education, and Welfare
Office of Education
Bureau of Education for the Handicapped

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CHAPTER I

INTRODUCTION

A. Scope of the Project

After several years of research at Stanford University and Stanford Research Institute, investigators involved in the Optacon projects became convinced in 1969 that an effective new reading method for the blind was at hand. These investigators proposed in 1970 that an Optacon field trial program be initiated in elementary and secondary schools. This proposal triggered a sequence of events which eventually led to three separate contracts from the United States Office of Education. The contract for the engineering evaluation was awarded to Franklin Institute Research Laboratories (FIRL) in Philadelphia, Pennsylvania. The contract for the educational evaluation was awarded to the American Institutes for Research (AIR) in Palo Alto, California. This final report covers the third contract (OEC-0-71-4415 (607) for manufacture of the equipment required by the field trial, which was awarded to Telesensory Systems, Inc., commencing June 28, 1971. The objectives of this contract were:

1. The formulation of production designs for the Optacon, Tracking Aid, Tape Training Aid, and Visual Display Monitor.
2. The manufacture of fifty-three Optacons, twenty-one Tracking Aids, seven Tape Training Aids, nineteen Visual Display Monitors, and twenty-one Master/Slave cables.
3. The maintenance and updating of the equipment specified in #2 above until June 27, 1973.
4. The maintenance of liaison with the teachers and students participating in the field trial to obtain information important to the design of future models.

It is felt that all of the above objectives were successfully accomplished. In addition, other work not required by the contract was performed.

B. Background

The Optacon (OPtical-to-TActile-CONverter) is a direct-translation reading aid for the blind developed over the last ten years at Stanford University and Stanford Research Institute (SRI). For the past five years, the project at Stanford has been supported by the Office of Education

under Grant No. OEC-0-8-071112-2995. Since the final report of that project, dated March 1973, contains a complete account of Optacon development, the historical content of this report will be limited.

The Optacon substitutes the sense of touch for the sense of vision using electromechanical means. With one hand the blind user scans a camera unit across the printed material to be read. The index finger of his other hand is placed on the tactile screen output unit. A moving tactile image of the printed material, taken one letter at a time, is displayed to the fingertip by the tactile screen. As its name implies, the Optacon simply duplicates printed material, converting it to a magnified, tactile facsimile that the blind user can perceive.

At Stanford and SRI, the Optacon project progressed through feasibility determination and several generations of hardware. A number of engineering innovations successfully surmounted various technical problems. By 1970, ten portable Optacons had been fabricated, and several were in daily use by blind individuals. Blind users, in fact, were becoming quite possessive with respect to "their" machines. This fact, plus encouraging quantitative data from reading studies, led key participants of the Stanford/SRI project to conclude that the Optacon was sufficiently developed to warrant its widespread dissemination.

Since Optacon manufacturing and distribution activities were not suited to the University or SRI, Telesensory Systems, Inc. (TSI) was incorporated in mid-1970 to be the vehicle for these purposes. The founders of TSI were closely connected to the early work, and felt an obligation to see that the research and development at Stanford and SRI had a useful impact for the sightless. TSI is now a small, independent company devoted at present exclusively to activities related to the Optacon.

In late 1970, TSI proposed an Optacon field trial program in elementary and secondary schools. The manufacturing contract of this final report resulted. In addition, as mentioned above, educational and engineering evaluations are being conducted under United States Office of Education sponsorship independent of TSI.

C. The Equipment Manufactured

Figure 1 is a photograph showing the types of equipment supplied by TSI under this contract. These are Optacons, Optacon Cassette Trainers, Visual Displays, Tracking Aids, and Master/Slave Cables.

1. The Optacon -- the key equipment unit provided, appears on the left side of Figure 1. Its operation was described briefly above. The camera unit is shown attached to the main instrument via its lightweight umbilical cord. The instrument is battery powered and portable, being approximately the size and weight of a normal dictionary.
2. The Visual Display -- the unit on the right side of Figure 1 with the handle on top. It is an auxillary instrument that, when plugged into an Optacon, displays visually the tactile image displayed to the blind reader. It is of value for training, demonstrations, and Optacon trouble-shooting.
3. The Tracking Aid -- the mechanical device on the right hand side in the front of Figure 1. It mechanically guides the camera along the line of print. It is used in early training so that the trainee can concentrate on tactual perception of lettershapes without the necessity of freehand tracking.
4. The Optacon Cassette Trainer (OCT) -- the embodiment of the tape training unit described in Section I-A. The OCT allows letter patterns to be automatically displayed on the tactile screen of an Optacon in "Times Square Sign" fashion at adjustable rates. Lessons are stored on specially coded cassette magnetic tapes that are inserted into a modified cassette tape recorder. Any normal Optacon can be "slaved" to the lettershape signals generated by an OCT. The OCT is designed for improving tactile letter recognition skills and building up reading speed. The OCT is the large instrument in the center of Figure 1.
5. The Master/Slave Cable (not pictured in Figure 1) -- a simple electrical cable that enables one Optacon, the "master," to

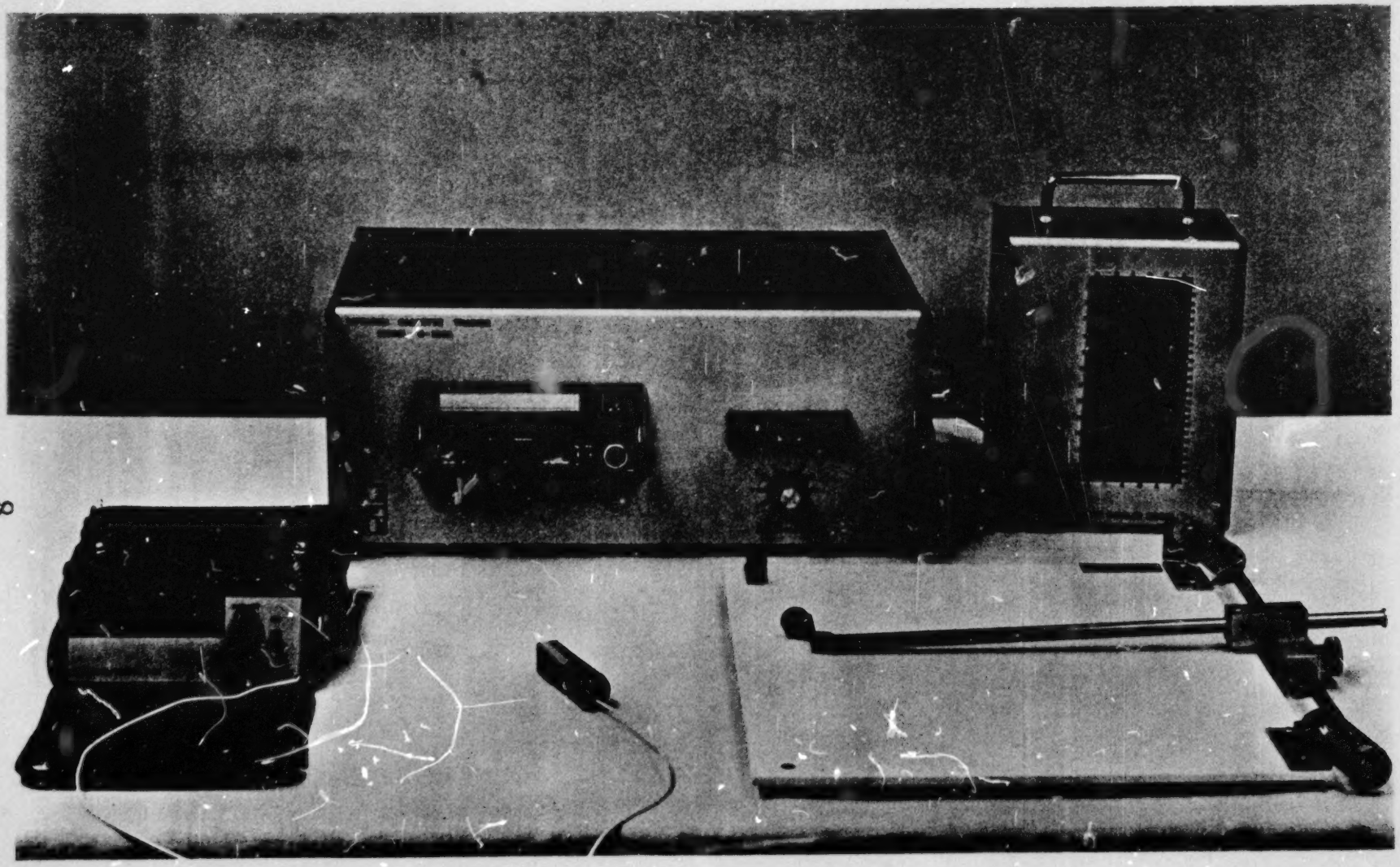

Figure 1

The Optacon (Camera on the Right), Optacon Cassette Trainer, Tracking Aid, and Visual Display

control the tactile screen of another "slave" unit. This cable provides flexibility for training more than one student at the same time, plus allowing a blind teacher-student combination.

D. Key Accomplishments of this Contract

1. TSI Has Been Established as a Viable Entity. This contract was a key factor in the formation of TSI. A commercial enterprise devoted to sensory aids is an essential link to complete the symbiotic University-Industry-Government relationship needed for the effective dissemination of technological aids for the handicapped.

2. Production Designs Established. Production designs were generated for the equipment manufactured. Tooling, manufacturing procedures, quality control procedures, and documentation for the equipment manufactured were developed.

3. All Equipment Delivered on Schedule. All of the equipment described above was manufactured and delivered on time in accordance with schedules established in conjunction with United States Office of Education, AIR, and FIRL.

4. New Tape Training Unit Designed. Although not required by the contract, the new Optacon Cassette Trainer was designed and developed by TSI for use in the Educational Evaluation at no additional cost to the Government.

5. New Tracking Aid Designed. A new Tracking Aid was developed and designed by TSI to be compatible with the new type of Optacon to be manufactured.

6. Rapid Service and Engineering Response. To facilitate the Educational Evaluation, TSI has strived for a one-day turnaround of any equipment returned for service. Close monitoring of the field program is maintained so that design deficiencies that emerge can be quickly remedied.

CHAPTER II

ENGINEERING DESIGN OF EQUIPMENT

A. Engineering Goals

At the outset of this project, a hand-tooled prototype Optacon (designated S-15) had been completed at Stanford University, and an improved unit utilizing printed circuit cards (S-16) was under construction. A prototype Visual Display had also been built at Stanford. This equipment was of a new "hybrid" electronics generation, different from the fourteen units that had been previously used. Since this new generation had not been field tested, additional engineering improvements by TSI were expected to be needed. Also, neither a tape training machine nor a tracking aid had been designed that was compatible with the new Optacon generation.

Engineering goals of TSI were thus to product-design the hybrid "1971" Optacon prototype, along with its attendant Visual Display, Tracking Aid, and tape training aids. Changes were effected wherever it was felt that cost, performance, or reliability could be improved. Another important goal was to document the design by means of drawings and reports. In the following sections, a brief summary of the salient engineering activities is given.

The Optacon is a rather sophisticated instrument, and it would be false to imply that further improvements can not or will not be effected. Design improvement is a process without a well-defined point of completion, and as field trial experience is accumulated, and quality and performance standards are ever tightened, further design improvement of an evolutionary nature can be anticipated.

B. Optacon Engineering Activities

1. Electronic

   . A significant change in the electronic design was made to improve the comparator circuits. This change resulted in improved tactile images, especially at low battery voltages.

   . A printed circuit card was designed for the preamplifiers in the camera.

   . The printed circuit card for each column of the stimulator array was modified so that it can be plugged into a printed circuit connector for functional checking of the column.

   . A document "Circuit Description of the Optacon Model R-1B" was prepared.

. A protective circuit breaker was added to the electronics.

. The stimulator array wiring harness was changed from magnet wire to conventional wire for easier assembly and greater reliability.

. An adjustment potentiometer was added to the electronics to compensate for variations of retina sensitivity.

. The metalization pattern on the retina was redesigned to minimize edge effects that cause nonuniform photosignals.

. A component defect was discovered in one of the commercial integrated circuits (RCA CD4019). The component was inadequately protected against failure due to static electricity effects. The manufacturer was consulted and is taking corrective action. The circuitry was modified to prevent further failures.

2. Mechanical

. The camera lens zoom mechanism was simplified.

. A protective cover glass was added to the retina.

. A vinyl cover was added to the stimulator array to improve appearance and prevent tampering.

. A change from anodized to painted chassis was instigated.

. A special strain relief was designed for the camera cable attachment to the retina module.

. Front and rear nameplate panels were designed.

. The chassis drawings were finalized, and a number of small changes made for easier production and assembly.

. A complete set of camera drawings was prepared and a tolerance study completed.

. A hardwood case, with cut-out foam inserts and silk-screened lettering was designed.

. A cardboard shipping case, with special foam inserts and screened lettering was designed.

C. Visual Display Engineering Activities

. Printed circuit boards were designed for the various sub-assemblies.

. A package, consisting of a modified commercial unit was chosen. The various necessary chassis modifications were documented.

. A shipping carton with foam inserts was designed.

. When shipping experience evidenced a problem due to damage, the "on-off" toggle switch design was changed to utilize a low-profile rocker switch. All field units are gradually being retrofitted with this change.

. A document "Circuit Description of the Visual Display Model V-1" was prepared.

D. Tracking Aid Engineering Activities

At the onset of the project, no Tracking Aid was available to go with the "1971" hybrid Optacon, so this design project was undertaken and completed by TSI. A unique feature of the TSI-designed Tracking Aid is that the cross-bar arrangement is rotate 90 degrees from previous SRI devices, allowing finer control of small horizontal tracking movements. Considerable trial and error was required to locate a satisfactory bearing-shaft combination for the Tracking Aids.

E. Tape Trainer Engineering Activities

A tape training machine to be used with the 1971 Optacon was developed by TSI. This project required a significant design effort, although it was not an obligation of TSI under the contract.

The unit developed, designated the Optacon Cassette Trainer (OCT), stores one hour of lessons on a magnetic tape cassette. In operation, up to four Optacons and a Visual Display are connected to the OCT unit. The OCT simulates moving the Optacon camera at a fixed rate across printed material. The pre-recorded lessons are presented to the student in the form of alphanumeric characters moving across the tactile screen. The presentation rate is variable over a four-to-one range.

The basic OCT concept, the circuitry, and the mechanical design were accomplished by TSI. In addition, a machine was developed for recording and duplicating cassettes, and a computerized capability established for converting lessons into the tape format. Documents describing the OCT and its operating instructions were prepared.

CHAPTER III
MANUFACTURING ACTIVITIES

A. General

The bulk of activity sponsored by this contract was devoted to manufacturing of the equipment supplied. These manufacturing activities consisted of much more than the actual physical assembly operations. Since Optacons had never been produced before except on a hand-tooled basis, an entire manufacturing operation had to be established. This large task consisted of many facets: the hiring and training of personnel, the locating and qualification of vendors, the design and purchase of tooling to reduce parts cost, the establishment of an inventory control system, the establishing of assembly procedures, construction of jigs, fixtures and test equipment, and the setting up of quality assurance and incoming inspection standards and procedures.

The establishment of Optacon manufacturing capability and the actual production of equipment took long hours, and was not done without occasional setback. The present Optacon manufacturing operation is still being tuned, but it would not be "on the road" without the initial impetus supplied by this contract. In the following sections, some of the high points of the manufacturing activities are reported.

B. Vendor Location

Vendors had to be located for all of the catalog and custom parts used in the equipment. This time consuming and at times discouraging task will not be recounted in detail. As an example, the initial run of silicon retinas, which tested good, were almost totally destroyed by the vendor during packaging. The second run was properly packaged, but the sealing technique developed at Stanford was found to be inadequate. The third run was bad, at which time the vendor became bankrupt, and a new supplier had to be located.

We have, where possible, tried to establish multiple sources for critical parts, and purchase as economically as possible. Since quantities are not large compared to most production operations, savings obtained have not been comparable to "mass-production" economics.

C. Production Tooling for Vendor-Fabricated Parts

"Hard" tooling was obtained for several Optacon parts, thus reducing individual part cost in return for an initial investment. Particular tooling items included:

. A die for cutting out the material for the Optacon leather case.

. Tooling to injection mold rather than machine the stimulator array finger plate, giving approximately a two orders of magnitude cost reduction.

. Dies for injection molding several camera parts.

. A die for cutting out the Optacon front panel nameplate.

. A numerical-control program to punch out chassis parts.

. All printed-circuit board artwork for the equipment manufactured (twelve different boards).

. Silk-screen artwork for various nameplates and inscriptions on shipping containers.

. Tooling to punch Visual Display and OCT chassis parts.

. Tooling for the stimulator array vinyl cover.

. Tooling (masks) for custom integrated circuit fabrication and wafer testing.

D. Production Fixtures and Test Equipment for Manufacturing at TSI

Design and construction of equipment to facilitate production, testing, and burn-in constituted a major portion of the manufacturing effort. This task required close coupling between engineering and manufacturing personnel. Among the equipment designed were:

. Printed circuit board functional testers for Optacon and Visual Display.

. A tactile screen tester capable of exciting individual stimulator pins.

. A tester for the bimorph driver integrated circuit.

. A tester for the retina integrated circuit.

. A burn-in fixture for light-emitting diodes.

. Various special alignment fixtures for tactile screen fabrication.

. A retina alignment jig for the camera.

. Special jumper cards for printed circuit board testing.

. Electronics for camera testing.

. A printed circuit card to facilitate proper retina wiring.

. An optical tester for the retina module.

. Burn-in fixtures for Optacon circuitry.

. Various special tools and fixtures to facilitate camera fabrication.

. A battery charger tester.

E. Other Manufacturing Activities

Specific steps required for the various manufacturing processes were established, and occasionally modified. Standards for various key parameters were set up. Inspection steps for incoming parts, work in process, and final assemblies were determined. An inventory control system was established. A parts numbering system was devised. An orderly scheme for initiating engineering changes was put into effect. In essence, all of the necessary mechanisms for orderly production of a quality product were created.

F. Equipment Production

The actual production of the equipment was organized into a number of production runs, once the groundwork described above was established. Outside vendors were utilized to obtain most raw materials, machined parts, printed circuit cards, etc., and TSI activities were primarily devoted to putting together the various subassemblies and assemblies. Much of the work, especially tactile screen and retina module assembly, was done under the microscope. A highly skilled corps of workers was recruited and trained for the various tasks.

The original time schedule was targeted for delivery of all equipment by July 28, 1972. When it became clear that the Educational and Engineering Evaluations would not require delivery at that time, shippings were rescheduled for August 30, October 9, November 6, and December 3. Equipment was delivered directly to the American Institutes for Research (AIR) or directly to the evaluation sites selected by AIR on the required dates, except for some units shipped to FIRL for evaluation or directly to the Office of Education.

G. Problems

It can be appreciated that "growing pains" are inevitable when an organization becomes established, and of course many problems large and small were encountered. Difficulties with the custom retina integrated circuit retinas

were alluded to earlier. Another serious problem that emerged was caused by a manufacturing defect in the stimulator arrays that caused, after a period of operation, a number of stimulators to cease vibrating. Fortunately, this defect was discovered in time to repair (with considerable effort) all machines ready for shipment.

Despite occasional setbacks, all equipment was finished on time and within budget. Equally importantly, an Optacon manufacturing capability was established that now continues to grow and improve.

CHAPTER IV

FIELD TRIAL SUPPORT ACTIVITIES

A. Scope of Activity

The role of TSI with respect to the educational and engineering evaluations presently underway has been primarily that of a supplier of equipment. The Franklin Institute is evaluating the equipment supplied with regard to engineering effectiveness, and the American Institutes for Research is conducting the field trial to test educational effectiveness at various public and private schools throughout the country.

In the supplier's role, TSI has supplied documentation to FIRL, has trained personnel at the various school sites on how to operate the equipment, has conducted a follow-up visit to the various schools to check that all equipment is operating properly, and has repaired and updated equipment in the field.

B. Liaison with the Franklin Institute

TSI supplied equipment (4 Optacons, 4 Visual Displays, 2 Tracking Aids, 4 Master/Slave Cables, and 2 Optacon Cassette Trainers) and documentation to FIRL to facilitate the various tests and evaluations being conducted. During July 31 - August 2, 1972, TSI conducted a seminar at Palo Alto for FIRL personnel at which time the operating principles and design of the equipment were described in detail. On April 9, 1973 a documentation package was sent to FIRL with drawings of all the fabricated parts, custom integrated circuit fabrication details, assembly drawings, and circuit schematics and descriptions. TSI also supplied to FIRL a special tactile screen tester, like that used for production, that enables any individual stimulator to be excited. Relations with FIRL have been cordial and professional and all conclusions and recommendations of the FIRL study will be carefully considered.

C. Liaison with the Educational Evaluation

1. Site Visits. Once all of the equipment had been delivered from AIR to the field trial sites, a TSI representative visited that site in order to be sure that everything arrived in good condition and to train the on-site personnel to operate the equipment. In general, people had little difficulty in learning how to use the Optacons and supporting equipment. Teachers were instructed to follow the written instructions contained in the Optacon owner's manual and

were given a short training session in the operation of the equipment. A subsequent call was made to each site in order to check out and update the equipment, and to assist the program in any other way. These visits were scheduled after the equipment was used in order to catch any equipment problem that emerged.

Table I summarizes the visits paid by TSI to the various field sites. The first entry is the initial training visit at each location, and second (and sometimes third) is the equipment checkout visit. The right-hand column lists the Quarterly Progress Report where a detailed account of the visit appears.

2. Service Experience. It was felt by TSI that quick, efficient servicing of the equipment supplied was necessary for a meaningful field trial evaluation. Therefore, a policy was established that, if at all possible, any equipment returned to TSI for repair would be fixed and returned within one day. One person was assigned to be responsible for equipment maintenance, and service procedures and documentation were established. Though service performed was considerable, it is not felt that the evaluation program suffered due to excessive equipment unreliability.

Equipment service activity has been concentrated in three areas: 1) updating of equipment in accordance with the most-recent TSI standards; 2) repair of mistreated equipment, and 3) repair of equipment failures.

Several engineering changes were instigated during the field trial in order to improve performance or reliability, and these changes were made as a routine element of service. An example is the application of flat black paint to reduce unwanted reflections in the camera.

In general, the equipment was very well cared for during the field trial. However, the school environment is rugged for any equipment, and especially so when blind children are involved, so a few repairs were precipitated because of equipment damage.

Since an analysis of failures to establish Optacon reliability

Table I

RECORD OF SITE VISITS (OTHER THAN FOR SERVICE)

Site	Dates Visited	TSI Representative	Reported In
Azusa Unified School District	January 9, 1973	Bill Young	QPR VII, App. I
	March 20, 1973	J. Beard & P. Obester	QPR VII, App. III
Berkeley Unified School District	January 9, 1973	Carolyn Weihl	QPR VII, App. I
	April 30, 1973	John Beard	QPR VIII, App. I
Campbell Union High School District	December 12, 1972	Bill Young	QPR VI, App. I
	January 11, 1973	Bill Young	QPR VII, App. I
	March 28, 1973	J. Beard & C. Albin	QPR VIII, App. I
Campbell Union Elementary School District	October 10, 1972	Bill Young	QPR VI, App. I
	March 28, 1973	J. Beard & C. Albin	QPR VIII, App. I
Cincinnati Public Schools	November 28, 1972	Carolyn Weihl	QPR VI, App. I
	March 22, 1973	Carolyn Weihl	QPR VII, App. III
Chula Vista, California School District	February 8, 1973	Gale Lutz	QPR VII, App. I
	April 13, 1973	Gale Lutz	QPR VIII, App. I
Florida School for the Deaf & Blind	December 14, 1973	Dave and Sue Voorhees	QPR VII, App. I
	May 14, 1973	Paul Obester	QPR VIII, App. I
Garden Grove Unified School District	December 5, 1973	V. Proscia & A. Miller	QPR VI, App. I
	no second visit --- dropped out of the program		
Houston, Texas Independent School District	January 15, 1973	Clark Albin	QPR VII, App. I
	April 16, 1973	Paul Obester	QPR VIII, App. I
Logan School, Philadelphia, Penna.	October 27, 1972	Steve Brugler	QPR VI, App. I
	March 19, 1973	Clark Albin	QPR VII, App. III
Overbrook School, Philadelphia, Penna.	October 27, 1972	Steve Brugler	QPR VI, App. I
	February 14, 1973	Steve Brugler	QPR VII, App. III
	March 19, 1973	Clark Albin	QPR VIII, App. I

Table I (continued)

RECORD OF SITE VISITS (OTHER THAN FOR SERVICE)

Site	Dates Visited	TSI Representative	Reported In
Perkins School for the Blind Watertown, Mass.	December 11, 1972 March 20, 1973	Dave and Sue Voorhees Clark Albin	QPR VII, App. I QPR VII, App. III
South Salem, Oregon High School	December 21, 1972 April 18, 1973	B. Young and C. Albin John Beard	QPR VII, App. I QPR VIII, App. I
San Diego, California City Schools	Not Applicable	Gale Lutz	
Visalia, California Unified School District	January 6, 1973 March 14, 1973	Dave and Sue Voorhees Clark Albin	QPR VII, App. I QPR VII, App. III

in schools is a task of FIRL, a detailed summary of equipment failures will not be given in this report. As stated above, the educational evaluation was never threatened due to equipment problems. Some failures are inevitable, but the goal of course is to maximize reliability while preserving reasonable cost. We have noted that there have been roughly 20% more service calls on the Optacons in the OE evaluation than with other TSI customers, presumably because of the more rugged school environment. While all basic designs are considered sound, some areas have been identified where reliability improvement is desired:

1. The battery life has been shorter than expected.
2. Battery chargers have been prone to failure or diminished current capacity.
3. Improved camera cable strain relief is desired.
4. One commercial integrated circuit (CD 4019) has been prone to fail. This problem was eventually proven to result from a defective vendor supplied part.
5. The tactile screen pins sometimes jam, catch on the finger, or vibrate weakly.
6. The Cassette Trainer tape recorder is prone to excessive mechanical wear.

As a result of service experience, two specific actions were taken in the form of a letter sent to all field trial sites:

1. A letter warning instructors to beware of camera cable twisting. Inexperienced Optacon users or students will sometimes continually rotate the camera cable until it becomes tightly twisted. While no known failures have occurred from this action, it is a bad practice easily forstalled by proper instructions.
2. A letter recalling Visual Displays for "on-off" switch change. If a Visual Display is used with an ungrounded receptable, and the on-off toggle-type switch has been damaged, then a potentially dangerous voltage might be shorted to the Visual Display chassis. For this reason, the unit was redesigned to use a low-profile rocker-type switch, and TSI offered to change all Visual Displays in the field.

Another problem discovered from field experience was the tendency of a few tactile screen pins in an array to short through the insulation and become connected to the drive voltage waveform. After careful study, this situation was not deemed to be a serious problem and at no time was any danger of harmful effects on humans evidenced. It has, however, been remedied for all future production units.

D. Other Field Activities

Although not supported by this contract, it should be mentioned that TSI has acquired a large backlog of experience through a number of Optacon programs throughout the world. At present, approximately 300 Optacons have been manufactured and deployed. Individuals, State, Federal, and Private Agencies, Corporations, Universities, and School Systems have participated in a wide variety of programs directed toward Optacon dissemination. TSI has established training capability in Palo Alto, prepared training materials, and recruited and trained a devoted corps of teachers. Only through continued and varied programs can manufacturing, training, and equipment engineering be continually improved so that the Optacon's promise is fulfilled.

CHAPTER V

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

A. Results

The salient results of this contract, as mentioned in Chapter I were:

1. Government support provided the impetus for the establishment of TSI as a viable entity.
2. Production designs were established for the Optacon, Visual Display, Tracking Aid, Cassette Tape Training Aid, and Master/Slave Cable.
3. Fifty-three Optacons, twenty-one Tracking Aids, nineteen Visual Displays, seven Cassette Tape Training Aids, and twenty-one Master/Slave Cables were manufactured and delivered on schedule.
4. New Cassette Tape Training Aid and Tracking Aid designs were established.
5. Fast service response minimized equipment down time during the educational evaluation.

TSI has continued manufacturing and distributing Optacons and related equipment. Production efficiencies enabled in good measure by this contract allowed TSI to announce a 30% Optacon price reduction in March, 1973.

B. Conclusions

1. Optacon and Support Equipment are Manufacturable Items

   Via this contract, proof that the Optacon and related support equipment can be successfully manufactured was established. The custom integrated circuits needed were procured from commercial vendors. The tactile screen, for the first time, was manufactured in quantity by a number of trained assemblers. Through careful planning and hard work, the hand-made University-developed prototype was found to be amenable to production-line assembly.

2. Optacon "Mass-Production" Not Achieved

   In spite of the past and continuing investment in manufacturing tooling, and an expansion in production rate, the number of Optacons being manufactured still falls short of optimum in the economic sense. TSI is a very small operation. Time after time, economical purchasing has been hampered because of too-small quantities desired. Overhead relative to direct manufacturing labor is too

high. Only through an order-of-magnitude increase in manufacturing rate can real "mass-production" economies be approached.

3. Equipment Proven in Schools

Schools provide a rugged environment for equipment, giving a severe test both to design and manufacturing integrity. It is felt that the equipment supplied demonstrated its worth in this respect, as well as providing useful information for further improvement.

4. Importance of Training and Service with Deployment

Several experiences during the course of the contract underscored the need for proper training and service during the course of a project. Sometimes, equipment problems were actually operator problems. Conversely, faulty equipment was not always detected. Instructors need to learn equipment principles and operating procedures. Students must be properly introduced to the equipment and trained to develop good habits. Quick turnaround service is essential to keep continuity and ensure a successful program.

C. Recommendations

1. Design Engineering Improvements and Attachments to Present Optacon

It has become clear that Optacon usefulness in both school and vocational settings will be enhanced if various attachments can be made available to the basic unit. These attachments will extend the utility of the machine for specialized reading tasks. Attachments are being designed or contemplated for:

a) Reading cathode-ray tube computer terminals
b) Reading hand-held calculators
c) Reading while typing
d) Reading while handwriting
e) Increasing or decreasing the size of characters to be read.

Problem areas with respect to reliability were mentioned in Chapter IV. Remedial steps are being undertaken. Two areas of desired improvement that will require considerable time and effort are:

a) Improve tactile screen long-term reliability. A promising approach to this end is to seal the unit so that the vibrating pin contacts the finger through a protective membrane rather than directly. The membrane would prevent the pins from catching and the holes from becoming clogged. The best choice for a membrane material is not known at this time.

b) Reduce tactile screen audio noise. This noise is seldom bothersome to the user, but can become annoying to nearby persons, especially in a classroom. The vibrating reeds for the screen are inherently noise-producing, and various experimental attempts to diminish it have thus far met with limited success. We have yet to address ourselves fully to this problem.

2. Further Research Needed for Second-Generation Optacons

At Stanford University, work is continuing that it is hoped will lead to more effective Optacons in the future. Broad goals are reduced costs, increased reading speeds, and ease of use. A "one-hand" Optacon simulation has been put together for trial. Research also is needed in underlying integrated circuit technology, psychophysical reading phenomena, and instrument development. This research must continue in order to pinpoint fundamental limits and point the way for better Optacons in the years to come.

3. Present Optacon Must be Disseminated

Based on other successful programs, TSI is confident of favorable results from the evaluations now being independently conducted. We feel the Optacon should and will have a profound and pervasive influence on the education of the blind. Much work remains. To start with, findings of this and related studies must be widely distributed. New programs must be instigated, and funding allocated.

4. Equipment Supplied Must be Utilized and Maintained

In the original proposal for this project, TSI advocated that students successfully trained be allowed to retain their Optacons. Such a distribution would leave the equipment where trained personnel exist, and would enable trained students to benefit from their efforts. Follow-on studies could also be conducted. It

is hoped that such an arrangement is possible.
Regardless of where the equipment is used, provisions are needed to continue equipment maintenance and updating. As mentioned previously, effective service is an essential component of Optacon deployment. A follow-on service contract to TSI is suggested for this purpose.